

TAP 408-2: Potential near a charged sphere

In this demonstration, you will be using a “flame-probe” to measure potentials around a charged sphere. The flame probe itself requires a little trickery to get the gas flow exactly right – you may want to play around with the probe well before trying to show this to a class!

The flame is required to cause ionisation in the surrounding air to allow the probe to take on the potential of the point where it is placed.

Introduction

A flame probe provides a convenient way of measuring the potential at a point in an electric field. In this investigation, you will be able to look at the variation in potential in the space around a charged metal sphere. You do this by fixing the potential at one end of a voltmeter, so converting all measured potential differences to potentials, by sharing a common origin.

You will need:

- ✓ metal sphere about 15 cm in diameter with long connecting lead
- ✓ insulated support for the sphere
- ✓ demonstration digital multimeter
- ✓ EHT power supply, 0–5 kV dc
- ✓ clip component holder
- ✓ 10 M Ω resistor
- ✓ 4 mm leads
- ✓ metre rule
- ✓ flame probe
- ✓ retort stand, boss and clamp
- ✓ gas supply
- ✓ calibration coil



Wire carefully, EHT voltages

School EHT supplies have an output limited to 5 mA or less which makes them safe. In this experiment, very low currents are sufficient so the extra resistor (e.g. 50 M Ω can be included in the circuit is it is built into the supply.

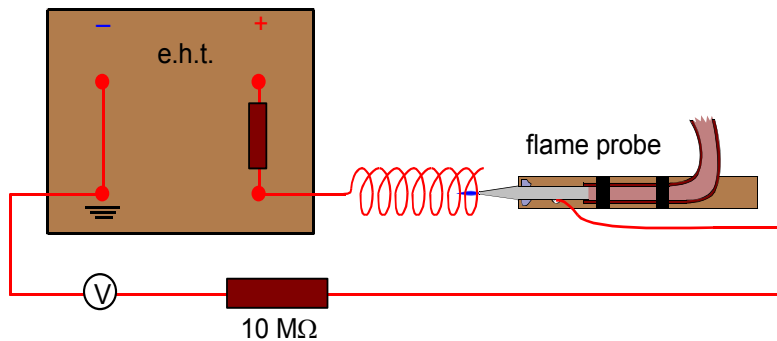
Note the high voltage on the sphere, the naked flame on the flame probe and the sharp point on the hypodermic needle

TAP 409-2: Flame probe construction

Checking and calibrating the flame probe

Before you can measure how the potential difference changes as you move between the plates, check the action of the flame probe.

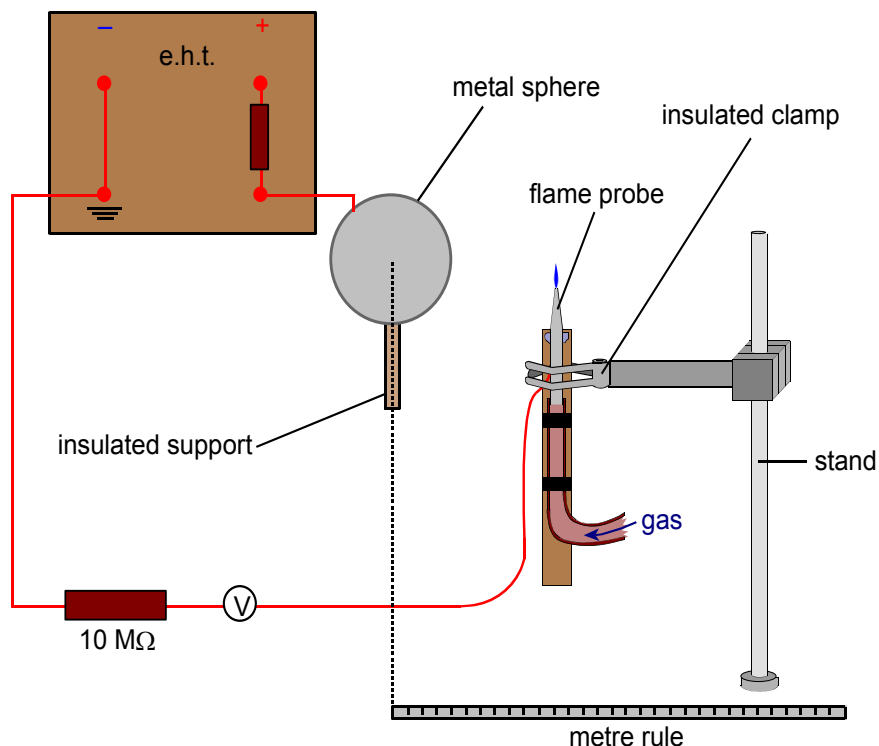
Everywhere inside the copper coil is at the same potential above 0 V. You can see that the flame probe measures the potential difference above ground in this space by altering the output pd on the EHT power supply.



You can use this arrangement to calibrate the flame probe, matching the numbers on the EHT power supply to the numbers appearing on the multimeter. Note that the multimeter is only measuring a fraction of the pd, as it forms part of a potential divider.

Measuring potential differences

You are now in a position to measure how the potential difference changes at different locations near the metal sphere.



Explore the region around the sphere.

Place the flame probe a few centimetres from the surface of the sphere.

The multimeter reads a fraction of the potential at this point. If you move the flame around the sphere keeping the distance from the centre constant, you will notice that the voltmeter reading does not change. You are following an equipotential. Think carefully about what shape this is; what does this tell you about the field lines?

Return the flame probe to a position close to the sphere and fix a ruler to the bench so that you can measure the distance of the probe from the centre of the sphere. By taking measurements of the potential at increasing distances from the sphere, you will be able to plot a graph of the potential against distance from the centre of the sphere, and by analysing this you should be able to confirm that the potential varies as $1/r$.

Outcomes

You have found:

- 1) That the equipotentials are spherical and are centred on the centre of the sphere while the field lines are radial.
- 2) The graph of potential against distance shows that the potential near a charged sphere varies as $1/r$, where r is the distance from the centre of the sphere.

Practical advice

The metal sphere has to be mounted in an insulated stand so that it is supported about 30 cm above the bench. The positive terminal of the EHT power supply has to be connected to the sphere. The earthed negative terminal is connected to a terminal of the multimeter.

The sphere needs to be conducting and about 150 mm diameter. Mounting the metal float from an old water cistern on an insulated rod and supporting this in a wooden retort stand is a convenient solution.

There are further construction details for the flame probe in the Teacher and technician information.

A suggested sequence

Place the flame probe a few centimetres from the surface of the sphere. Turn on the gas supply and wait for a few seconds before trying to light the gas as it takes some time to clear the air out of the tubing. Once there is a flame, you will be able to adjust its size with the Hoffmann clip; a small flame is best.

The multimeter reads a fraction of the potential at this point. If you move the flame around the sphere keeping the distance from the centre constant, you will notice that the voltmeter reading does not change.

Return the flame probe to a position close to the sphere and fix a ruler to the bench so that you can measure the distance of the probe from the centre of the sphere. By taking measurements of the potential at increasing distances from the sphere, students will be able to plot a graph of the potential against distance from the centre of the sphere.

An extension might be to use a twin flame probe to look at potential gradients.

Technician note

Details of the flame probe construction are given in

TAP 409-2: Flame probe construction



Wire carefully, no bare wire above 40 V

School EHT supplies have an output limited to 5 mA or less which makes them safe. In this experiment, very low currents are sufficient so the extra resistor (e.g. 50 M Ω) can be included in the circuit if it is built into the supply.

Note the high voltage on the sphere, the naked flame on the flame probe and the sharp point on the hypodermic needle

External reference

This activity is taken from Advancing Physics chapter 16, 200D